McGill University

Earth & Planetary Sciences

Alumni Newsletter #18 May 2016

The photo above shows the volcanoes of Bromo (mid-ground at 7,641 ft or 2,329 m) and Semeru (background at 12,060 ft or 3,676 m), both found on the island of Java, Indonesia. These two volcanoes are very active. Continuous small eruptions occur about every 20 minutes on Semeru while fumarole activity is ongoing in the crater of Bromo. Every few years large eruptions happen as well.

The distinctive line in the midground (center of photo) results from an atmospheric inversion layer.
On this day, it could be seen to descend with time.
One hour before sunset, you were in the clouds surrounded by mist.
Near sunset, however, the inversion layer dropped below you, creating this interesting line effect.
It might not look like it, but the cone of Bromo was only about 2.5 mi (4 km) away;
Semuru was approximately 14 mi (22 km) away.
This is due to the fact that above the inversion layer the atmosphere is usually exceptionally clear.
Photo taken on July 23, 2015.

Note from the Chair

Good news coming our way as we anxiously greet the arrival of Spring. After a number of years of budget cuts in education, funding of education has become a priority at both the Provincial and Federal levels and instead of facing further budget cuts, as the McGill administration had anticipated and planned for for the 2017 fiscal year, we can expect some reinvestments in post-secondary education. Like every other academic unit within the University, the Department of Earth and Planetary Sciences suffered over the last few years, mostly through the loss of support staff, but we have fared better than most thanks to the generosity of our many donors, alumni and friends. Targeted, strategic and discretionary gifts have allowed our students to seamlessly sail through their residency at McGill and benefit from new teaching and research initiatives as well as memorable experiences in the field. One of the new teaching initiatives (EPSC-240; Geology in the Field) as well as some of the most recent field trips are featured in this newsletter, including the Volcanology field trip to the U.S. Northwest, the sedimentology field trip to Southeastern Spain, the Willy trip to South Africa and our new combined Field School II & III (another new teaching initiative) to the Massif Central in France, all of which would not have been possible without contributions from our faithful donors. Whereas a number of field trips were carried out locally, you may wonder why the aforementioned field trips were out of the country. This is what I meant by strategic gifts, as some of our donors, after consultation with the Chair and the Faculty of Science Advancement Office, requested that their gift go towards the support of international field trips and in doing so had their gifts matched by another fund.

Starting with this issue of the newsletter, our Editor, Anne Kosowski, decided that for this and future issues we should highlight a specific sub-field of geosciences. In this issue, we feature Volcanology. It is only fitting that we do so at this time, as Prof. John Stix, one of our resident volcanologist and esteemed colleague, was awarded the Principal's Prize for Teaching this past year. This is the most prestigious teaching award bestowed to faculty in the University. As you can guess, it takes a very special kind of teacher to be nominated for and awarded this prize, so read all about it in this newsletter.

As I step down from the Chair at the end of May and pass the helm to the caring hands of Jeffrey McKenzie, I wish him the best during his term, thank my faculty colleagues and staff for their support over the past three years, and reiterate my gratitude to our donors for greatly buffering the challenges of recent budget cuts and allowing our students to experience the best that the Department could offer.

Alfonso Mucci
Chair, Department of Earth and Planetary Sciences

Geology in the Field
EPSC 240

New course taught by Christie Rowe

In Fall 2015 I piloted a new course for U1 students, EPSC240: Geology in the Field. The motivation for designing this course was based on feedback from alumni and members of the department that indicated a demand for expanding field mapping in our undergraduate program.

Daphne Saint Denis striking the plate with a sledge hammer during seismic survey on lower campus field

It is commonly acknowledged that map comprehension and mapping skills are essential for many career paths in industry. In particular, exploration geologists and prospectors work with geologic maps on a daily basis, and many of our graduates have pursued these careers in recent years. Mapping skills benefit earth scientists across many other specialties, even if they are not directly engaged in mapping. Research has shown that field mapping experience contributes to a better understanding of spatial scale, a sense of the interaction between map and landscape, and an ability to integrate a multiplicity of geologic information into a single coherent picture (e.g. Lonergan and Andresen, 1988; Riggs et al., 2009). This kind of experience is useful to scientists across all disciplines.

With these goals in mind, EPSC240 was designed to emphasize time and experience in the field making primary observations. The students practice basic field methods and are introduced to the geology of Montréal and the Archean to Holocene history of Québec. We meet for one 50-minute lecture on Monday, and on Wednesday we spend the lecture period and 3-hr lab period in the field (most weeks).

Measuring dipping limestone beds on top of Mount Royal

In this first year, we ran most of our labs around campus and on Mount Royal. These included a pace and compass map, a topographic map exercise in the cemetery, field sketching (guided by Profs. Robert Mellin and David Covo from Architecture), a reflection seismic survey across the Lower Field, and practice describing rocks using the familiar Laval Formation limestones and outcrops of gabbro.

Class measuring section in the Champlain Sea Sediments

We also took a couple afternoons off the island to visit rocks with non-horizontal dips (at the Laval Nature Centre) and to measure a stratigraphic column in Champlain Sea sediments near Rougemont. When the weather got cold toward the end of the semester, we moved indoors to practice constructing cross sections off a geologic map, solving three-point problems using topographic information on geologic maps, and using Google Earth and Google Mars for a modern approach to photogrammetry. The capstone assignment of the course involved a term paper and presentation on a particular period/region of the local geological history, and the presentations were given in chronological order for an afternoon tour-de-force of Québec geology from the oldest Archean rocks to the modern sedimentary environment of the Saint Lawrence.

If this experiment is successful, I expect to see the result in the students this May at Field School 1. Although I'm sure their Brunton technique will be a bit rusty after the long winter, I hope the introduction activities of the fall will help the students hit the ground running when we arrive in Las Vegas, Nevada on May 1. We will use this skills boost from EPSC240 to elevate the level of Field School 1, to focus more on interpretation and understanding as the basic skills are already established.

Christie Rowe
Wares Faculty Scholar

References

Lonergan, N. and Andresen, L. W. (1988) Field-based education: some theoretical considerations. Higher Education Research & Development, v. 7 n.1 63-77.

Riggs, E. M., Lieder, C. C., and Balliet, R. (2009) Geologic problem solving in the field: Analysis of field navigation and mapping by advanced undergraduates. Journal of Geoscience Education v. 57, n. 1, 48-63.

1st Year Field Trip
Friday, September 18, 2015

Montreal lies within the St. Lawrence Lowland geological province and is characterized by the presence of a striking topographic feature on the island, Mont Royal. Mont Royal is part of the Monteregian Hills, igneous plugs intruded into the surrounding Paleozoic platform sedimentary rocks that, in this area, are more than 2 km thick! And the morphology and young sedimentary rocks of the region reflect modification by recent glaciers (~18ka).

This year's field trip was led by Bill Minarik and Jamie Kirkpatrick and participants began the trip by walking from the FDA Building to Mont Royal via the McTavish walkway. Their 1st stop was the outcrop near the plaque at the base of Mont Royal where they observed the fossiliferous Trenton Group. From there, they continued walking up the stairs to the Lookout (overlook – Stop 2) at the top of the mountain - stopping along the way to look at the Utica shale, and cross-cutting dikes. The Utica Shale lies stratigraphically above the Trenton Group. From the top of Mont

Royal you can see the regional geology overview: Monteregian Hills, glaciations stratigraphy, tectonic setting during the Cambrian-Ordovician. At Smith House on Mont Royal, they boarded a bus to travel to LaPrairie (QC) to visit Hanson Brickyard (Stop 3) where they could observe and collect fossils. They then traveled to Pointe de Bussion Archeological Park located near the rapids between the St. Lawrence River and Lake St. Francis to visit the Point de Buisson Fossil Museum (Stop 4) which contains Ameridian artifacts as well as a Fossil Garden assembled largely by Pierre Groulx, and the newly build “Hans Hofmann Hall’ dedicated to Hans Hofmann’s (Ph.D. ’62) research work as a professor and paleontologist. Their final stop before returning the McGill was the Coteau du Lac Historic Site (Stop 5) – one of the first portage sites to bypass rapids along the St. Lawrence River. This site hosts a wonderful exposure of the early Ordovician Beauharnois Fm, part of the Beekmantown Group – the dolostone that can be seen within the old locks contains stromatolites and chert nodules/lenses.

Earth System Science

Orientation – Mont St Hilaire

02-04 October 2015

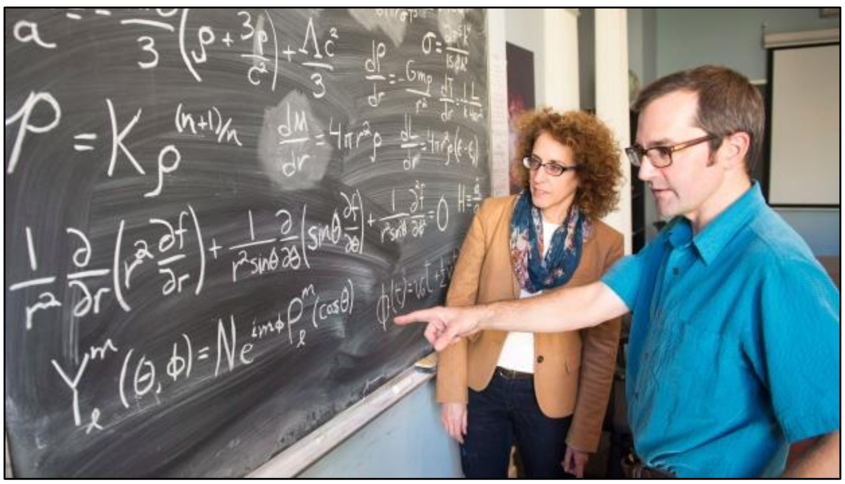
Left to Right: Cyann Dias, Anna Hayden, John Stix, Wonjun Cho, Ammar Adenwala, Claire Bernard-Grand'Maison, Kathryn Elmer, Erik Johnson and Bill Minarik

John Stix, Wonjun Cho, Erik Johnston Anna Hayden, Kathryn Elmer, Cyann Dias and Claire Bernard-Grand'Maison

Wonjun Cho, Erik Johnson, Anna Hayden, Claire Bernard-Grand'Maison, Cyann Dias, and John Stix

McGill Space Institute

Montreal’s emergence as a leading hub for space research takes another big step forward with the launch of the McGill Space Institute (MSI) on October 28th, 2015. The MSI, led by renowned astrophysicist Victoria Kaspi (2016 recipient of the Gerhard Herzberg Canada Gold Medal for Science and Engineering), will bring together researchers specializing in astrophysics and cosmology, planetary science, atmospheric science, astrobiology and other space-related sciences in order to enable collaboration that could lead to breakthroughs in solving some of the most fundamental questions in science – from the evolution of the universe and the nature of gravity, to the search for extraterrestrial life. One topic of focus is the study of extrasolar or exoplanets, or planets orbiting a star other than the sun as there has been an explosion of discoveries of these planets in recent years thanks to new high-powered telescopes. McGill scientists from a cross-section of backgrounds will work in communication with their counterparts from the Université de Montreal’s Exoplanet Institute to study their properties, climates and structures – research that could lead to the discovery of life.



Director of the new McGill Space Institute (MSI), Victy Kaspi, and EPS Professor Boswell Wing look over an equation in Montreal on October 30, 2015.

Kelly Lepo (MSI Coordinator), Boswell Wing, Vicky Kaspi, Robert Archibald (Physics Ph.D. Student), Tracy Webb (Physics Prof), Natalya Gomez (EPS Professor) and Holly Han (EPS Ph.D. Student)

Geological Association of Canada
Leopold Gélinas Gold Medal

Jason Coumans (Ph.D. '16) has been selected to receive the 2016 Geological Association of Canada's Leopold Gélinas Medal (Gold) for best Ph.D. thesis entitled *"Magmatic and volcanic processes at near-ridge seamounts"* (John Stix, supervisor).

Thesis Abstract:
Short chains of seamounts are common on the flanks of fast- to intermediate-spreading mid-ocean ridges in the Pacific Ocean. They have been studied extensively in order to understand the nature of off-axis magma production from melting anomalies in an upwelling mantle. One of the most important characteristics of near-ridge seamounts is their larger trace element and isotopic variation when compared to an adjacent spreading center. This larger variation implies that near-ridge seamount magma bypasses mixing and homogenization processes at the axial reservoir, thus making them excellent geologic targets for investigating heterogeneity in the depleted upper mantle. However, a number of important questions remain regarding the spatial and temporal scale of mantle heterogeneities, melting processes in the mantle, modification during transport to a shallow crustal reservoir, and magmatic processes occurring in a sub-caldera reservoir.

Taney Seamount-A, the largest and oldest seamount in the Taney near-ridge chain, exhibits complex shallow and surface processes such as repeated caldera collapses and explosive volcanism. Taney Seamount-A has four well-defined calderas with clear cross-cutting relationships, providing a relative chronology of volcanism. Therefore, Taney Seamount-A represents an ideal target site to investigate the unresolved questions outlined above. To address these questions, I have undertaken a multi-tiered approach incorporating submersible sampling and observation, geochemical analysis and modelling, and scaled analogue experiments.

Geochemical analyses and modelling of lavas, crystals, and melt inclusions show that the magmatic history beneath Taney Seamount-A is complex. Lavas vary from typical peridotite-derived mid-ocean ridge basalt compositions (N-MORB) to those with an apparent residual garnet signature. Geochemical modelling suggests that the observed garnet signature can be reproduced by decompression melting of a MORB mantle peridotite which has been re-fertilized by garnet pyroxenite partial melts. Large anorthite-rich plagioclase crystals entrained in lavas have textural evidence of melt-rock interaction. Furthermore, melt inclusions within plagioclase exhibit a non mantle-derived geochemical signal indicating partial melting of a plagioclase-rich cumulate.

Volatile saturation pressures from H2O-CO2 relationships in the melt inclusions imply that the large plagioclase crystals formed at the Moho. During transport from the mantle to a shallow magma reservoir, melts ponded at the Moho and underwent melt-rock interaction characterized by episodic partial melting, magma mixing, and recrystallization of plagioclase cumulates. Temporal changes of major elements of the lavas are consistent with an open-system sub-caldera reservoir that undergoes periodic caldera collapse, replenishment, shallow crystallization and eruption. In summary, the magmatic history at Taney Seamount-A comprises magma generation by melting of a two-component mantle, melt-rock interaction at the Moho, open system evolution in a sub-caldera magma reservoir, and caldera collapse.

Caldera collapse processes at Taney Seamount-A and other near-ridge seamounts are complex and

dependent upon the orientation of the edifice above the magma reservoir. Scaled analogue experiments of caldera collapse at near-ridge seamounts suggests that an offset position of the volcanic edifice induces a trapdoor style of caldera collapse. This style of collapse is characterized by initial subsidence on a reverse fault resulting in the buildup of antithetic flexural tension in a hinge area and formation of a graben structure. The tilting of offset near-ridge seamount calderas towards the ridge axis, as well as structures observed on trapdoor basaltic volcanoes, suggest that complicated asymmetric caldera collapse processes illustrated in analogue experiments also occur in nature.

The Volcanology and Igneous Petrology Division of the Geological Association of Canada annually presents three medals for the most outstanding theses, written by Canadians or submitted to Canadian universities, which comprise material at least 50% related to volcanology and igneous petrology. A gold (plated) medal is awarded for the best Ph.D. thesis, a silver medal for the best M.Sc. thesis and an antique copper medal for the best B.Sc. thesis. Nominated theses are evaluated on the basis or originality, validity of concepts, organization and presentation of data, understanding of volcanology, and depth of research. Awards are not made if the panel of judges considers that there are no worthy nominations.

Jason climbing Stromboi in Italy. Stromboli is one of the most active volcanoes on Earth and has been erupting almost continuously since 1932. Because it has been active for much of the last 2,000 years and its eruptions are visible for long distances at night, it is known as the "Lighthouse of the Mediterranean". It is among the world's most visited volcanoes.

Geological Association of Canada

Eric Mountjoy Exchange Award

Timothy Gibson (Ph.D. candidate) has been selected as the 2016 recipient of the Geological Association of Canada's Eric Mountjoy Exchange Award.

The Eric Mountjoy Award is available to encourage the exchange of young geoscientists between Quebec and other parts of Canada. The award is named after Eric Mountjoy, a distinguished Canadian professor of geology at McGill University, explorer, Fellow of the Royal Society of Canada, and recipient of the Douglas Medal of the Canadian Society of Petroleum Geologists and the Pettijohn Medal of the Society for Sedimentary Geology. He was renowned for his contributions to the understanding of sedimentary carbonate rocks, particularly those of Devonian age, in his pioneering geological explorations and geological maps and cross-sections of the Canadian Rockies, particularly in the region of Jasper National Park and Mount Robson Provincial Park.

Nominations of individuals for the Eric Mountjoy Award must be registered students or post-doctoral fellows at a Canadian university.

The annual award of up to $4,000 must be used to fund expenses related to an exchange in order to undertake scientific studies between a Quebec-based university/institution and a university/institution located elsewhere in Canada. The exchange can take place in either direction. A supporting faculty member from the candidate's home university is required to sponsor the proposal.

SAAEG Lifetime Achievement Award

Dr. Desh Sikka (Ph.D. ’60)

Felicitation Address
Presented with
Conferment of "LIFE TIME ACHIEVEMENT AWARD" by
SOUTH ASIAN ASSOCIATION OF ECONOMIC GEOLOGISTS (SAAEG)
in honour of

Dr. Deshbandhu Sikka

We, the members, office-bearers and patrons of the Association feel greatly privileged to present this citation in honor of Dr. Deshbandhu Sikka, on whom the SAAEG’s Life Time Achievement Award for the year 2015-16 is being conferred with a deep sense of gratitude and pride today, at the historic city of Gwalior in Central India.

Dr. Deshbandhu Sikka’s father, Dr. Gokul Chand Sikka, worked with Punjab Health Services as a General physician and eye Surgeon with good knowledge of Herbs and Homeopathy. He was endowed with a good healing hand. He and his wife Mrs. Vasheshran Sikka, were blessed with a son on 1st November, 1927 at Lyallpur (now Faisalabad, Pakistan). Bestowed with Patriotic fervor, the couple named their beloved son as Deshbandhu, after the honorific title of “Deshbandhu” Chittaranjan Das, a renowned freedom fighter of India.

Sikka had a good academic record. He received a B.Sc. degree (1945, Punjab University, now Pakistan) and a M.S. (1954) from New York University, NY, USA. He attended Bucknell University (1948) and Colorado School of Mines, Golden, Colorado (September 1948- July 1950) with options in mining geology and petroleum geology. His Doctoral Thesis at McGill University, Canada (1960) was on “Aero Radiometric Survey of Red Water Oilfield, Alberta, Canada” and he was awarded a Ph.D. funded by Imperial Oil Ltd. and Hans Lundberg Ltd.; for which he was awarded First prize and President's Gold Medal by the Canadian Institute of Mining, Metallurgy and Petroleum (CIM). His pioneering research on radiation surveys is applicable to the exploration of oil and gas, geological mapping, wall rock alteration, soil mapping (now being used in Agriculture) and overburden mapping. Radon can be used as a precursor for earthquake prediction.

Dr. Sikka returned to India in October1960. He worked as a Reader, Department of Geology, Punjab University, Chandigarh. In 1961 he joined the National Mineral Development Corporation Ltd. (NMDC) as Chief Geologist. He expanded the operations of NMDC from one geologist in 1961 to 70 geologists in 1966. In 1963, he proposed "A Scheme for Airborne Surveys" to be undertaken by NMDC which was approved by the Government of India in November 1964 as a key program to be carried out by the Geological Survey of India. With accomplishment of this program, India became the first country to undertake systematic Airborne Surveys that included Gamma-ray spectrometry. These surveys were followed-up by ground geophysical surveys, geological mapping, geochemistry and diamond drilling. This marked the beginning of modernization of Mineral Exploration and Development in India.

The enhanced activity in NMDC led to the discovery of several significant ore deposits that included the Kudremukh iron deposit (1964), Kolihan copper deposit (1966) and the Malanjkhand copper deposit (1971). Sikka became the Acting Chief Executive, Planning and Chief Geologist for Hindustan Copper Ltd. (1968). He pressed for detailed exploration, which included deep drilling and mine development work, leading to production of Copper at the Khetri and Kolihan deposits and development of lead at Agnigundala. In 1971, he became the Coordinator of the Malanjkhand deposit, which proved to be a significant world-class ‘porphyry copper’ deposit.

The introduction of Airborne and Ground Geophysical Surveys into India, discoveries of Kudremukh magnetite iron deposits and Malanjkhand porphyry copper deposit are major tributes to Sikka.

In 1972, Dr. Sikka joined a group of Geological and Mine Valuation Consultants in India and undertook consulting work on several projects, which included determining the sources and supply of Ilmenite from Australia, Egypt, India, Korea, Madagascar, Mozambique, South Africa, Tanzania, Canada, Norway and Sweden, as well as lithium sources from Goias, Brazil. Sikka has a rare and unique mastery of the Exploration of Magnetite Quartzites, Hematite ores, Copper ores, Lead – Zinc deposits, Gold, Titanium, Lithium sources, etc. to mention a few. In 1975, Sikka formed a consulting company, ‘Sikka and Associates Limited’, Nassau, Bahamas, and in 1982, converted it to Cabinet Conseiler Geologie Miniere Sikka Enr., Montreal, Canada, to continues his practice. In 2003 he incorporated Barfanisai Enterprises Inc., Montreal, a company for mineral exploration and development in India, and is its current President.

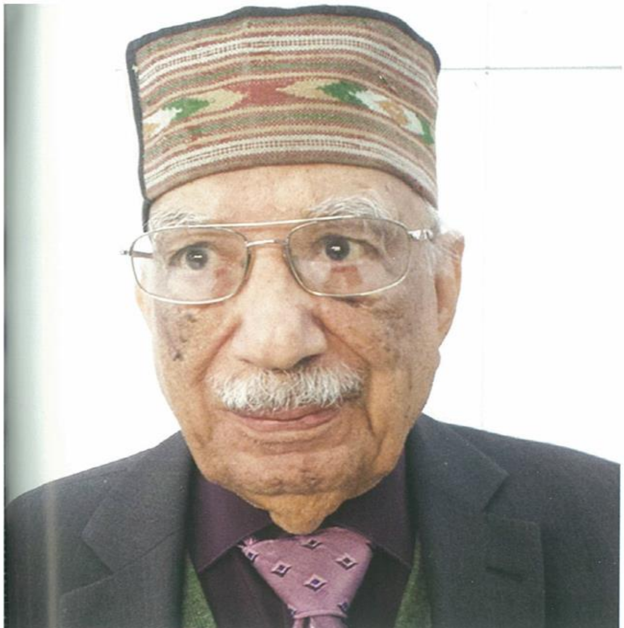
Dr. Sikka has authored over 36 scientific papers and 50 unpublished company reports. At the ripe old age of nearly 90 years, he continues to be productive in publishing papers on the geology and mining activities in India and abroad. His unique blend of scientific theory and practical knowledge has led him to come up with visionary ideas such as the concepts of primary deposition of Sulphides, and Sulphide remobilization for Indian deposits; although these ideas, initially faced resistance they are currently accepted. His ideas of extensive drilling and deep drilling of some of the Indian deposits were also opposed by local authorities initially, but have since been accepted. Dr.Sikka has actively promoted India's mining sector and its mineral endowment at many international conferences and also personally invested in India.

Dr. Sikka is a Life member/Fellow of many Professional bodies that include (CIM), Mining Metallurgical & Geological Institute of India (MMGI), Society of Applied Geologists and Technologists, Geological Society of India, South Asian Association of Economic Geologists /Association of Economic Geologists (India), Society for Geology Applied to Mineral Deposits, Prospector and Developers Association of Canada etc., to mention a few. Dr. Sikka has a facility with several languages and has been known to express his views and opinions openly and constructively. A practical mining geologist par excellence with rare academic bent of mind, Sikka is a visionary, effective administrator, a relentless fighter for the cause of Mineral Industry and a spiritual human being with great patriotic fervor.

Dr. Sikka lives in Montreal, Canada, with his wife Mrs. Mira Sikka whom he credits with his successes. They have two sons and a daughter and grandchildren living in India and in Montreal. May the Almighty shower His choicest blessings in all walks of life on Sikka and all members of his proud family.

In recognition to his life-long, laudable achievements and contributions in the field of Mineral Exploration, the South Asian Association of Economic Geologists (SAAEG), feels proud to confer the Association’s most prestigious honor “Lifetime Achievement Award” for 2015-16, on Dr. Deshbandhu Sikka.

Prof. K.L Rai	**Dr. A.S. Bhalla**	**Dr. P.S. N. Murthy**
President	*Chairman Organizing Committee, Gwalior*	*Vice-President, South Zone (SAAEG) &*
(SAAEG)	*Gwalior Convention of SAAEG (No. 2015)*	*Convener, Round Table Conference of Geoscientists, Gwalior*



DESHBANDHU SIKKA

Vision and Straight Talk

DR. DESHBANDHU SIKKA'S commitment to modernize India's mining sector began in 1960 and continues still at the age of 90. He is a world renowned geologist and mining expert whose international work includes in countries such as Brazil, Canada, Egypt, Greece, Sudan, Norway, Sweden, the USA and India. Despite obstacles in his dealings with Indian government agencies, Sikka's work has made a lasting contribution to India's mining sector.

He first went to the Colorado School of Mines where Dr. Kermit Herness was instrumental in getting Sikka interested in Economic Geology with a focus on Mining and Petroleum Geology.

Sikka did his MS in Geological Sciences at New York University and his Ph.D. at McGill University in Montreal in 1960 where he pioneered the development of gamma-ray spectrometry for oil, gas and mineral exploration with applications to soil mapping and potential use of radon as a precursor in earthquake prediction.

His mentor was none other than then Industries Minister of Tamil Nadu, R. Venkataraman, who later became the President of India. Sikka accepted a job offer from the National Mineral Development Corporation (NMDC). He was also with the Hindustan Copper Limited (HCL) but the work in India proved challenging for this man after his 13 years of education and experience in the US. To his bosses in India, Sikka's experience was theoretical and they did not want him to question any of their practices or reports.

Despite these obstacles and opposition from the Geological Survey of India (GSI) and the Indian Bureau of Mines (IBM) and their governing agencies, Sikka succeeded in introducing modern technology, airborne geophysical surveys, geochemical surveys and deep diamond drilling.

He discovered magnetite iron ore deposits for pelletizing at Kudremukh, Karnataka and the giant world class Malanjkhand porphyry copper /molybdenum/gold deposit with close to a billion tonnes @0.83 %Cu in Madhya Pradesh. The recommendation to develop the Malanjkhand mine as an open pit operation was rejected by the GSI. Sikka reminds people that he was the one who originally discovered the billion tonne Malanjkhand deposit.

With all kinds of obstructions in his innovative ideas, Sikka decided to return to Montreal to carry on his work in the geological field.

Sikka has promoted India's mining sector and its mineral wealth. "Many amongst the Indian Diaspora have skills, knowledge and experience which would be beneficial to India. Because of parochial interests, their patriotic fervor should not be questioned," he says.

This has been contributed by Indira Singh, Principal, Mining Consultancy International Inc. of Canada

THE A-LIST
2016

HIS CONTINUING EFFORTS, EVEN AT AGE 90 YEARS, HAVE MADE A LASTING CONTRIBUTION TO INDIA'S MINING SECTOR

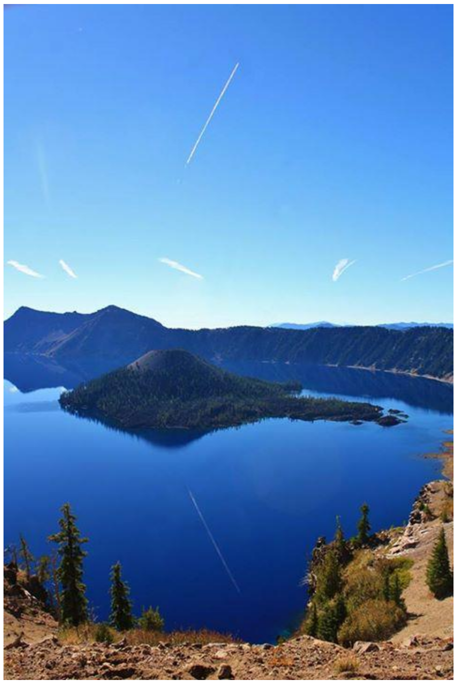
Volcanology
Cascades Field Trip
10-18 October 2015

Late on October 10th, a group of McGillian volcanologists-in-training arrived in Portland, Oregon. After one night in a roadside motel, we hit the road, travelling north across the Columbia River, to our first stop, Mount St. Helens.

By midday we arrived at Johnston Ridge, named posthumously for David Johnston, the USGS geologist famously known for radioing "Vancouver, Vancouver, this is it!" before being swept away in the immense lateral blast from the May 1980 eruption. From this incredible vantage, we surveyed the northern flank and the Sugar Bowl, and the devastated terrain below. A Forest Service Ranger gave a presentation on the mechanics of the eruption, from the incredible pre-eruption slope swelling, to the three-stage slope collapse that lead to such incredible regional destruction. We then hiked the ridge towards Spirit Lake, with spectacular views of Mount St. Helens, and a sunlit Mount Adams on the horizon.

The following day, we explored the undulating terrain near the North Fork Toutle River, where we climbed through the lumpy hummocks straddled by broad, flat lahar flows. There we found hummocks of variable type, including matrix supported, clast supported and mixed hummocks. By that afternoon we were on the road again, travelling south to Crater Lake.

The views of Mount St. Helens were breathtaking, but perhaps were rivalled by what we saw from the rim of Crater Lake. The pristine waters were gorgeous, reflecting the distant scalloped cliffs of the youthful caldera. Only the post-caldera cinder cone called Wizard Island (and a group of swimming McGillians) disrupted the water's stillness. Outcrop-to-outcrop we explored the Crater Lake area, identifying key features of the pre-, syn- and post-eruption geology.



In outcrops of early lava flows, we found many rounded enclaves which bore evidence of magma mingling. Along the caldera walls, we identified the proximal deposits of pumice fall that upsection abruptly turned to ignimbrite, corresponding to the immense collapse of the eruption's plinean column. Farther from the rim we found fumaroles, the large needle-like ignimbrites cemented by steam, and thus preferentially revealed by erosion.

Our last destination was farther south, in the Medicine Lake Highlands of California. At Lava Beds National Monument, we spent a day exploring the seemingly endless network of lava tubes, identifying pahoehoe, aa and drip textures. We saw remarkable examples showing the complex way in which lava could flow through the subterranean system, and urther, witnessed the incredible unique environment the lava tubes offered, such as the perennial ice that lay deep within at least one cave.

Our final full day of geology was spent further into the Medicine Lake Highlands, learning about the immense dacite and rhyolite flows that had intruded into the forest not so many thousands of years ago. At the rhyolite flow, most collected incredible specimens of the flow-banded glass, which lay strewn across the slopes. At the day's end, we stood atop Little Mount Hoffman and surveyed the lava flows below and a cloud-wrapped Mount Shasta. In the far distance, we could see just glimpses of Mount Lassen, marking the geographic end of the Cascade Volcanic Arc.

The journey back to Portland was a lengthy one. However, a short stop in Salem Oregon to enjoy the hospitality of the Roseborough family, who provided the entire group with a fantastic meal, was a welcomed break for which we were all grateful. By days end, we had reached the Pacific Ocean. There, we set up camp for one last night, and were treated to a spectacular sunset, marking an incredible conclusion to an incredible trip!

We are most grateful to the Department for providing financial support which made this trip possible

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Photo Credits:
Haylea Nesbit – Mt. St. Helens & Crater Lake
Gregor Lucic – Lava Tubes Group Shot

2015 Principal's Prize Excellence in Teaching John Stix

We are delighted to announce that John Stix has been chosen as the 2015 recipient of the Principal's Prize for Excellence in Teaching in the category of Full Professor in recognition of his exceptional contributions to teaching at all levels. John received his prize at the Fall 2015 Convocation on November 10th at Place des Arts.

John's eagerness and ability to communicate his love of science and volcanology is manifested by his hands-on approach to teaching. His enthusiasm and passion to impart students with the understanding of his science is evident when he provides cool demonstrations that are memorable which helps students understand the material. In addition, John has creatively integrated research in an undergraduate course (Natural Disasters) with an enrolment of 600 students, and has demonstrated leadership in online education over the past decade, including teaching one of McGill's first Massive Open Online Course (MOOC) on Natural Disasters. John has distinguished himself and honored our Department, Faculty, and University by his outstanding dedication to student learning.

"The most important qualities a teacher should have are patience and an ability to listen to the students," says John Stix, *"They have a lot to say."*

John has been fascinated by rocks and minerals since he was a young boy. *"It was natural for me to study geology,"* he says. *"But it was my first geology class as an undergraduate at Dartmouth College that did it for me. The class approached geology from the then-emerging paradigm of plate tectonics, and the professor teaching the class was great."* John teaches everything from a class in natural disasters to volcanology to earth sciences applications. John says the biggest challenge he faces in the classroom is the incredible diversity of students. *"I teach many different groups of students – non-science students, geology undergraduates and graduate students,"* he says. *"I enjoy doing all of this, but it does require different approaches and a different mentality in approaching the courses and students."* When asked if he would recommend teaching as a profession, John says, yes, because the student-teacher relationship can be mutually beneficial. *"It is a very rewarding experience, because not only do you learn a lot by teaching, you also can influence and nurture students as they learn and mature intellectually,"* says John.

What's Up with Volcano Research at McGill?

Professor Kim Berlo

Three students are currently working with me. Rebecca Paisley who started last year is working on the 2011 eruption of Cordon del Caulle in Chile. She is currently preparing for an exciting expedition to visit the crater area and the obsidian lavaflow. In her research she addresses the degassing history of the magma by studying the chemical variation in volcanic glass and short-lived radionuclides. The other two students, Shane and Sanita started only this year and are both working on different aspects of Krafla caldera. Shane is working with John Stix and myself to look into the petrogenesis of rhyolite. Sanita is interested in the processes occurring in the shallow plumbing system of rhyolite eruptions. Apart from helping the students with their research, my own research is focussed on the recent eruption of Chaiten volcano (Chile), understanding the processes that led to last eruption of Kawah Ijen (Indonesia) and the newly funded tandem Laser Induced Breakdown Spectrometer. The latter will bring a unique capability to McGill to analyse almost the whole period table at a micro-scale.

Professor John Stix

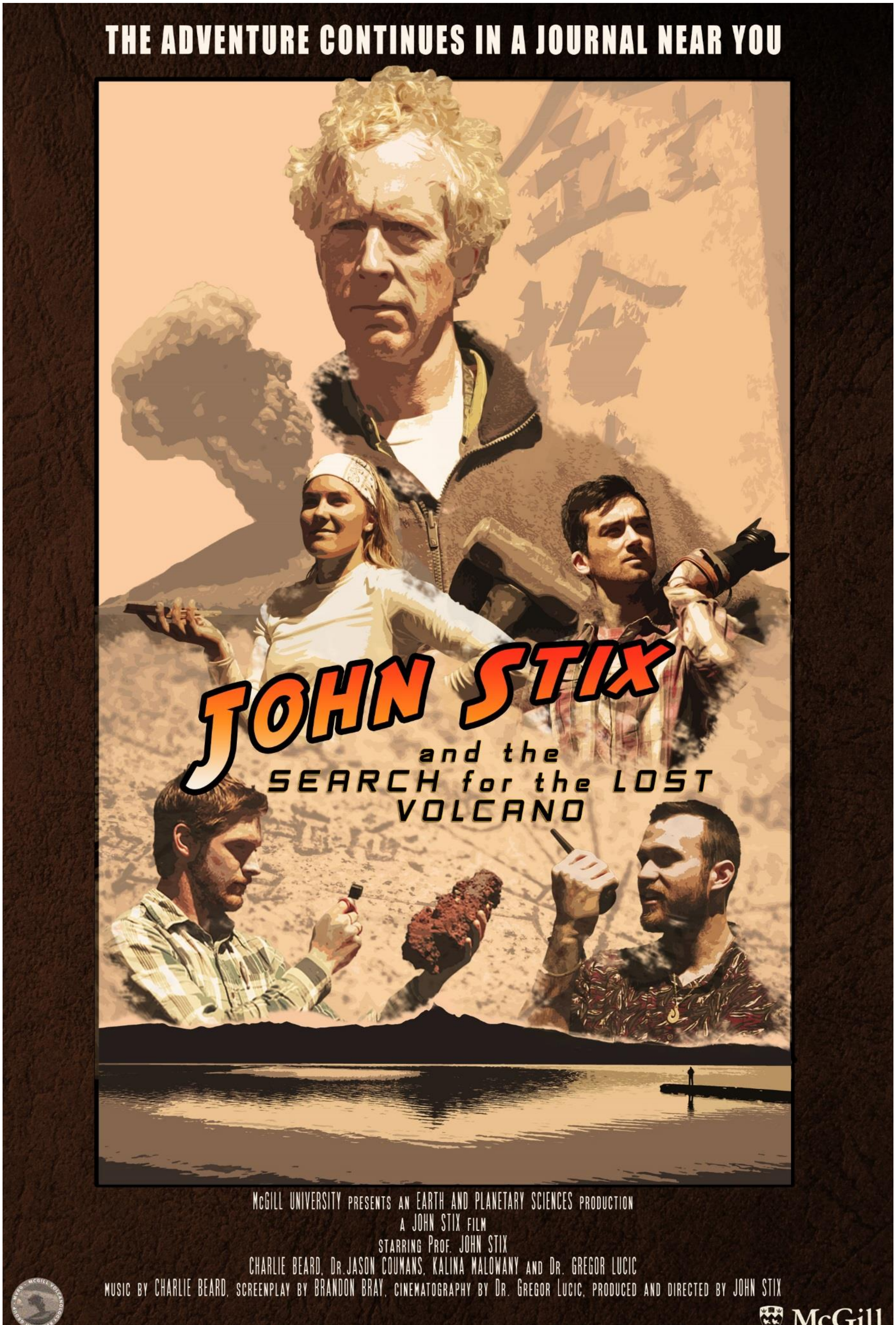
A great new crop of students have arrived recently, keeping me busy and on my toes. Clara Waelkens (PhD) is studying volatile evolution and magma replenishment at Valles caldera in New Mexico, one of the great supervolcanoes of the world. Shane Rooyakkers (PhD) is working with Kim Berlo and myself to unravel the geochemical and volcanologic evolution of Krafla caldera in Iceland, where molten rhyolitic magma was recently found (accidentally) at 2 km depth! Charlie Beard (PhD) is working with Vincent Van Hinsberg and me to understand how trace elements behave and partition in evolved alkaline systems through a series of novel experiments and fieldwork in the Canary Islands, notably Teide volcano in Tenerife, where the phonolites are green! Victoria Tweedie (MSc) is studying gases and fluids along the San Andreas Fault in California, comparing and contrasting creeping sections in Parkfield with locked sections further south in the Carrizo Plain where the last big earthquake occurred in 1857 and the region is now overdue! Fiona D'Arcy (MSc) is studying carbon and sulphur stable isotopes in tree rings from Turrialba volcano, Costa Rica, which have been affected by volcanic degassing and fumigation; she is also using a drone to measure carbon/sulphur ratios of Turrialba's plume. Gilles Seropian (BSc) is studying caldera collapse in the lab by instrumenting a sandbox with a magma chamber and observing fault formation as magma is withdrawn from the chamber. Carla Gonzalez (BSc) and David Martineau (BSc) are studying water and carbon dioxide in melt inclusions from Valles caldera to ascertain degassing histories at different moments in time. Gregor Lucic and Jason Coumans recently finished their PhD degrees; Jason is headed to Durham across the pond for a postdoc to study Katmai volcano, while Gregor will be working at Picarro Inc. in sunny California developing and applying new types of isotopic mass analyzers.

Drilling into magma

In 2009 the Iceland Deep Drilling Project unintentionally hit magma in Krafla caldera. This exploratory project aimed to reach supercritical fluids, which would drastically increase the power output of geothermal powerplants. The magma chamber underlying Krafla caldera had been imaged at about 4 km depth, and the target depth for the well was intended to get close, but not drill into the magma. Instead the drill bit got stuck at only 2.1 km depth and magma flowed a short distance up the hole! No magma was erupted. It is perhaps unsurprising to find magma in a caldera, but this is one of the best-monitored volcanoes in the world and the failure to detect a shallow magma body is a real worry. It could of course be the case that the reservoir is very small or was emplaced very recently. But if this was the case for this particular intrusion then perhaps there are others and the total volume of magma stored undetected in the shallow crust might be more significant than we think, not just at Krafla, but at other active and populated calderas. Apart from the concern regarding this undetected magma body, it represent unique opportunities to learn more about subsurface magma in calderas. With the aim to find out more about this magma body a new international effort (the Krafla Magma Drilling Project) is started to revisit this magma and find out much more about it.

John & Kim

The geothermal powerplant inside Krafla caldera


THE ADVENTURE CONTINUES IN A JOURNAL NEAR YOU
JOHN STIX
and the
SEARCH for the LOST
VOLCANO
McGILL UNIVERSITY presents an EARTH AND PLANETARY SCIENCES production
a JOHN STIX film
starring Prof. JOHN STIX
CHARLIE BEARD, Dr.JASON COUMANS, KALINA MALOWANY and Dr. GREGOR LUCIC
music by CHARLIE BEARD, screenplay by BRANDON BRAY, cinematography by Dr. Gregor Lucic, produced and directed by JOHN STIX
McGill

Ethiopia’s volcano burns deadly sulphuric gas

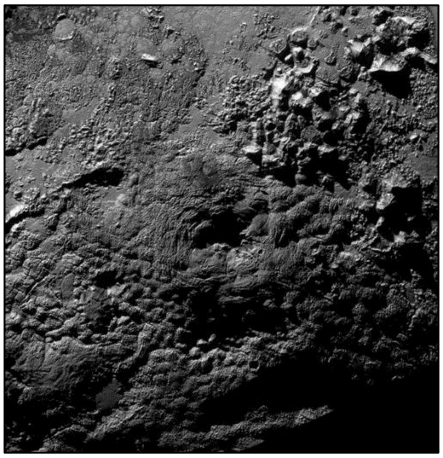
It’s a volcano, but not as we know it. This cerulean eruption takes place in the Danakil Depression, a low-lying plain in Ethiopia. The volcano’s lava is the usual orange-red – the blue comes from flames produced when escaping sulphuric gases burn

Ice Volcanoes

A cryovolcano (colloquially known as an ice volcano) is a volcano that erupts volatiles such as water, ammonia or methane, instead of molten rock. Collectively referred to as cryomagma or ice-volcanic melt, these substances are usually liquids and form plumes, but can also be in vapour form. After eruption, cryomagma condenses to a solid form when exposed to the very low surrounding temperature. Cryovolcanoes form on icy moons, and possibly on other low-temperature astronomical objects (e.g. Kuiper belt objects).

One potential energy source on some solar system bodies for melting ices and producing cryovolcanoes is tidal friction. It has also been suggested that translucent deposits of frozen materials could create a subsurface greenhouse effect that would accumulate the required heat.

Signs of past warming of the Kuiper belt object Quaoar have led scientists to speculate that it exhibited cryovolcanism in the past. Radioactive decay could provide the energy necessary for such activity, as cryovolcanoes can emit water mixed with ammonia, which would melt at 180 K (−95 °C) and create an extremely cold liquid that would flow out of the volcano.



A possible ice volcano on Pluto (visible at center) is seen in this NASA image, captured by the New Horizons spacecraft, released on Nov. 9, 2015. The feature, called Wright Mons, is a strange feature 100 miles wide and 13,000 feet high with a summit depression at its center. New Horizons scientists suspect Wright Mons and another mountain may be signs of cryovolcanic eruptions on Pluto

Hidden Superchain of Volcanoes Discovered in Australia

The newly discovered Australian volcano chain isn't a complete surprise, though: Geologists have long known of small, separate chains of volcanic activity on the island continent. However, new research reveals a hidden hotspot once churned beneath regions with no signs of surface volcanism, connecting these separate strings of volcanoes into one megachain.

That 1,240-mile-long (2,000 kilometers) chain of fire spanned most of eastern Australia, from Hillsborough in the north, where rainforest meets the Great Barrier Reef, to the island of Tasmania in the south. The track is nearly three times the length of the famous Yellowstone hotspot track on the North American continent.

Scientists had long known that four separate tracks of past volcanic activity fringed the eastern portion of Australia, with each showing distinctive signs of past volcanic activity, from vast lava fields awash in a volcanic mineral called leucitite that's dark gray to black in color. Some of these regions were separated by hundreds of miles, leading geologists to think the areas weren't connected. However, scientists suspected that the Australian volcanism had a common source: a mantle plume that melted the crust as the Australian plate inched northward over millions of years. (Whereas many volcanoes form at the boundaries of tectonic plates, where hot magma seeps up through fissures in the Earth, others form when mantle plumes, or hot jets of magma, at the boundary between the mantle and Earth's core reach the surface.) Scientists used the fraction of radioactive argon isotopes (versions of argon with different atomic weights) to estimate when volcanic activity first appeared in each of these regions. They combined this data with past work showing how the Australian plate had moved over the millennia. From this information, they could estimate where and when volcanism affected certain regions. Scientists found that the same hotspot, likely from a mantle plume, was responsible for all of the volcanic activity crossing eastern Australia. The new volcanic chain, which scientists dubbed the Cosgrove volcanic track, was formed between 9 million and 33 million years ago. (None of the volcanoes on Australia's mainland have been active during the recent past.) However, there are large gaps in volcanic activity on the surface of this track. To understand why, scientists modeled the thickness of the lithosphere, the stiff layer that forms the upper mantle and Earth's crust.

It turned out that, at certain spots along the Australian tectonic plate, the lithosphere was so thick that the mantle plume couldn't permeate all the way through to create melting the showed up at Earth's surface. However, at other points, the lithosphere was just barely thin enough to show the tiniest hints of magma at the surface. One of these spots is a region of northern New South Wales rich in leucitite, which contains high concentrations of potassium, thorium and uranium. Surface volcanism appeared only when the lithosphere was less than 81 miles (130 km) thick.

The new finds could help scientists model how mantle plumes interact with the continental crust to create volcanism.

Exerpt from Live Science
September 14, 2015

The 10 Biggest Volcanic Eruptions in History

#10 – Hyaynaputina, Peru - 1600

This peak was the site of South America's largest volcanic eruption in recorded history. The explosion sent mudflows as far as the Pacific Ocean, 75 miles (120 km) away, and appears to have affected the global climate. The summers following the 1600 eruption were some of the coldest in 500 years. Ash from the explosion buried a 20-square-mile (50-square-km) area to the mountain's west, which remains blanketed to this day. Although Huaynaputina is a lofty 16,000 feet (4,850 meters), it's somewhat sneaky as volcanoes go. It stands along the edge of a deep canyon, and its peak doesn't have the dramatic silhouette often associated with volcanoes. The 1600 cataclysm damaged the nearby cities of Arequipa and Moquengua, which only fully recovered more than a century later.

Lavallée, Y., S. de Silva, G. Salas, and J.M. Byrnes, 2006. Explosive volcanism (VEI 6) without caldera formation: insight from Huaynaputina volcano, southern Peru. Bull. Volcanol., 68: 333-348.

Lavallée, Y., S. de Silva, G. Salas, and J.M. Byrnes, 2009. Structural control on volcanism at the Ubinas, Huaynaputina, and Ticsani Volcanic Group (UHTVG), southern Peru. J. Volcanol. Geotherm. Res., 186: 253-264.

#9 – Krakatoa, Sunda Strait, Indonesia - 1883

The rumblings that preceded the final eruption of Krakatoa (also spelled Krakatau) in the weeks and months of the summer of 1883 finally climaxed with a massive explosion on April 26-27. The explosive eruption of this stratovolcano, situated along a volcanic island arc at the subduction zone of the Indo-Australian plate, ejected huge amounts of rock, ash and pumice and was heard thousands of miles away. The explosion also created a tsunami, whose maximum wave heights reached 140 feet (40 meters) and killed about 34,000 people. Tidal gauges more than 7,000 miles (11,000 km) away on the Arabian Peninsula even registered the increase in wave heights. While the island that once hosted Krakatoa was completely destroyed in the eruption, new eruptions beginning in December 1927 built the Anak Krakatau ("Child of Krakatau") cone in the center of the caldera produced by the 1883 eruption. Anak Krakatau sporadically comes to life, building a new island in the shadow of its parent.

#8 – Santa Maria Volcano, Guatemala - 1902

The Santa Maria eruption in 1902 was one of the largest eruptions of the 20th century. The violent explosion came after the volcano had sat silent for roughly 500 years, and left a large crater, nearly a mile (1.5 km) across, on the mountain's southwest flank. The symmetrical, tree-covered volcano is part of a chain of stratovolcanoes that rises along Guatemala's Pacific coastal plain. It has experienced continuous activity since its last blast, a VEI 3, which occurred in 1922. In 1929, Santa Maria spewed forth a a pyroclastic flow (a fast-moving wall of scalding gas and pulverized rock), which claimed hundreds of lives and may have killed as many as 5,000 people.

#7 – Novarupta, Alaska Peninsula - June 1912

The eruption of Novarupta one of a chain of volcanoes on the Alaska Peninsula, part of the Pacific Ring of Fire was the largest volcanic blast of the 20th century. The powerful eruption sent 3 cubic miles (12.5 cubic km) of magma and ash into the air, which fell to cover an area of 3,000 square miles (7,800 square km) in ash more than a foot deep.

Stix, J., and T. Kobayashi, 2008. Magma dynamics and collapse mechanisms during four historic caldera-forming events. J. Geophys. Res., 113: B09205. doi:10.1029/2007JB005073

#6 – Mount Pinatubo, Luzon, Philippines - 1991

A stratovolcano located in a chain of volcanoes created along a subduction zone, the cataclysmic eruption of Pinatubo was a classic explosive eruption. The eruption ejected more than 1 cubic mile (5 cubic kilometers) of material into the air and created a column of ash that rose up 22 miles (35 km) in the atmosphere. Ash fell across the countryside, even piling up so much that some roofs collapsed under the weight. The blast also spewed millions of tons of sulfur dioxide and other particles into the air, which were spread around the world by air currents and caused global temperatures to drop by about 1 degree Fahrenheit (0.5 degree Celsius) over the course of the following year.

Dartevelle, S., G.G.J. Ernst, **J. Stix**, and A. Bernard, 2002. Origin of the Mount Pinatubo climactic eruption cloud: implications for volcanic hazards and atmospheric impacts. Geology, 30: 663-666.

#5 – Ambrym Island, Republic of Vanuatu - 50 AD

The 257-square-mile (665-square-km) volcanic island, part of a tiny nation in the southwestern Pacific Ocean, witnessed one of the most impressive eruptions in history, one that sent a wave of scalding ash and dust down the mountain and formed a caldera 7.5 miles (12 km) wide. The volcano has continued to be one of the most active in the world. It has erupted close to 50 times since 1774, and has proved a dangerous neighbor for the local population. In 1894, six people were killed by volcanic bombs and four people were overtaken by lava flows, and in 1979, acid rainfall caused by the volcano burned some inhabitants.

#4 – Ilopango Volcano, El Salvador - 450 AD

Although this mountain in central El Salvador, just a few miles east of the capital city San Salvador, has only experienced two eruptions in its history, the first known eruption was a doozy. It blanketed much of central and western El Salvador with pumice and ash, and destroyed early Mayan cities, forcing inhabitants to flee. Trade routes were disrupted, and the centers of Mayan civilization shifted from the highland areas of El Salvador to lowland areas to the north and in Guatemala. The summit's caldera is now home to one of El Salvador's largest lakes.

Mann, C.P., **J. Stix**, **M. Richer**, and **J.W. Vallance**, 2004. Subaqueous intracaldera volcanism, Ilopango caldera, El Salvador, Central America. Geol. Soc. Am. Spec. Pap., 375: 159-174.

Richer, M., **C.P. Mann**, and **J. Stix**, 2004. Mafic magma injection triggering eruption at Ilopango caldera, El Salvador, Central America. Geol. Soc. Am. Spec. Pap., 375: 175-189.

#3 – Mt Thera, Island of Santorini, Greece - ~1610 BC

Geologists think that the Aegean Islands volcano Thera exploded with the energy of several hundred atomic bombs in a fraction of a second. Though there are no written records of the eruption, geologists think it could be the strongest explosion ever witnessed. The island that hosted the volcano, Santorini (part of an archipelago of volcanic islands), had been home to members of the Minoan civilization, though there are some indications that the inhabitants of the island suspected the volcano was going to blow its top and evacuated. But though those residents might have escaped, there is cause to speculate that the volcano severely disrupted the culture, with tsunamis and temperature declines caused by the massive amounts of sulfur dioxide it spewed into the atmosphere that altered the climate.

Parks, M.M., S. Caliro, G. Chiodini, D.M. Pyle, T.A. Mather, **K. Berlo**, M. Edmonds, J. Biggs, P. Nomikou, and C. Raptakis, 2013. Distinguishing contributions to diffuse CO_2 emissions in volcanic areas from magmatic degassing and thermal decarbonation using soil gas ^{222}Rn–δ^{13}C systematics: Application to Santorini volcano, Greece. Earth Planet. Sci. Lett., 377-378: 180-190.

#2 – Changbaishan Volcano, China/North Korea border - 1000 AD

Also known as the Baitoushan Volcano, the eruption spewed volcanic material as far away as northern Japan, a distance of approximately 750 miles (1,200 kilometers). The eruption also created a large caldera nearly 3 miles (4.5 km) across and a half-mile (nearly 1 km) deep at the mountain's summit. It is now filled with the waters of Lake Tianchi, or Sky Lake, a popular tourist destination both for its natural beauty and alleged sightings of unidentified creatures living in its depths. The mountain last erupted in 1702, and geologists consider it to be dormant. Gas emissions were reported from the summit and nearby hot springs in 1994, but no evidence of renewed activity of the volcano was observed.

#1 – Mt Tambora, Sumbawa Island, Indonesia - 1815

The explosion of Mount Tambora is the largest ever recorded by humans, ranking a 7 (or "super-colossal") on the Volcanic Explosivity Index, the second-highest rating in the index. The volcano, which is still active, is one of the tallest peaks in the Indonesian archipelago. The eruption reached its peak in April 1815, when it exploded so loudly that it was heard on Sumatra Island, more than 1,200 miles (1,930 km) away. The death toll from the eruption was estimated at 71,000 people, and clouds of heavy ash descended on many far-away islands.

2015 Thomson House Christmas Party Photos

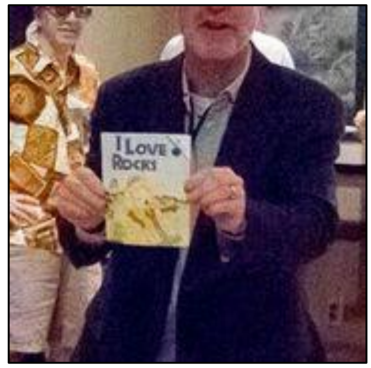











I LOVE ROCKS

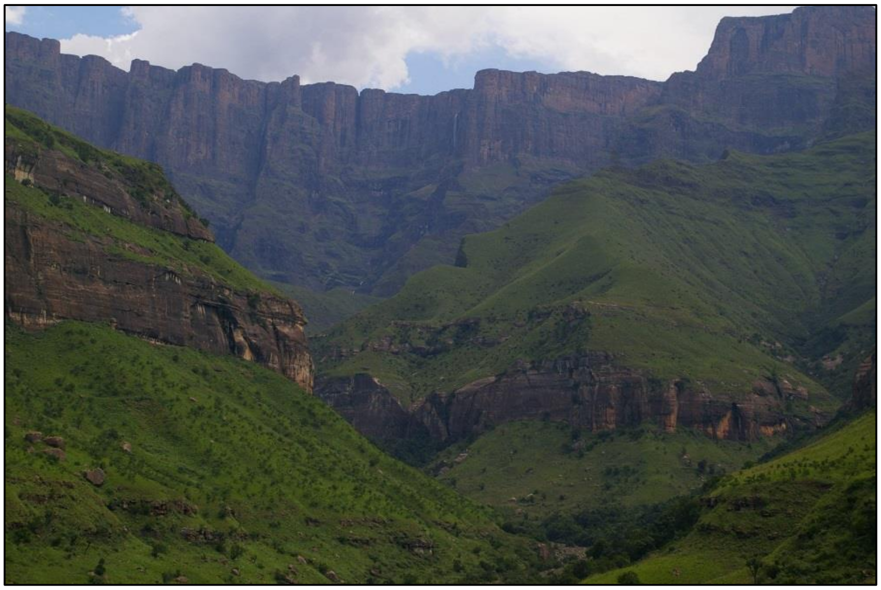







GEOLOGY SUPERHEROS

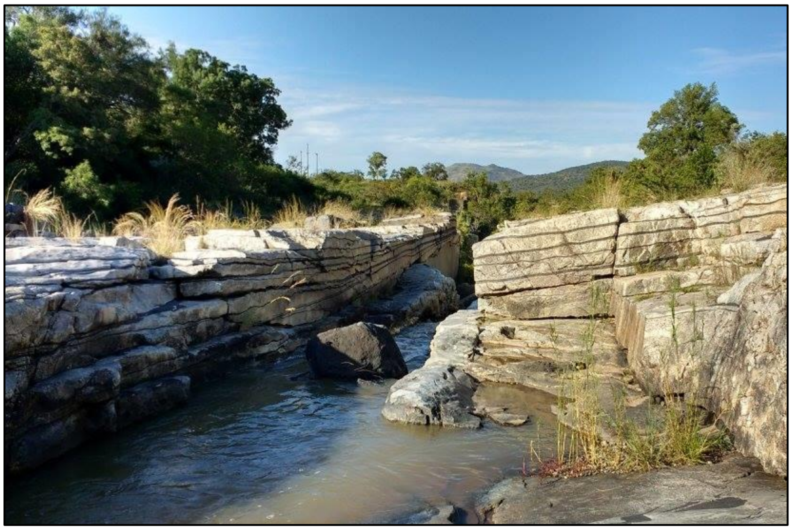
Willy Trip 2016
South Africa



This year, attendees of the Willy Trip had the privilege of visiting one of the most geologically stunning countries on Earth. From meteorite impact sites to mine visits, our trip was packed with incredible experiences. In this day-to-day summary, we will share the sights we saw, the geology we learned, and more!

February 29th, 2016 (Day 1)

From the patio of our Johannesburg hostel, we began our geological exploration of South Africa. Willy provided a brief overview of the country's tectonic history, including craton formation and the history of the Witwatersrand basin. Specific attention was given to the Bushveld Igneous Complex, where our first outcrop visits were for the day. The Bushveld Igneous Complex is an immense mafic layered intrusion, and is extensively mined for gold, platinum group metals (PGMs) and more. For the first day of our trip, we investigated just a select portion of the bushveld, the narrow chromitite bands of the UG1 reef. At the Dwars Rivier outcrop of the UG1, we noted that the chromitite layers had a distinct undulation, which we inferred to be evidence of the topography of the surface on which the chromite crystals settled. We also noted that not all of the bands were necessarily the same width or spaced equally. The formation of this reef has been the subject of a great deal of study. One camp of thought suggests that incorporation of silicic country rock into the mafic magma pushed the cooling m elt to crystallize chromite which could then settle. In time, the melt would return towards equilibrium, until the system was subjected to another silicic contamination event. Another proposed theory for generating these unique features is the mixing of two distinct magma compositions, also resulting in chromite crystallization. Since these distinct bands extend for hundreds of kilometers throughout the Bushveld, the scaling of any model proposed has proved challenging.

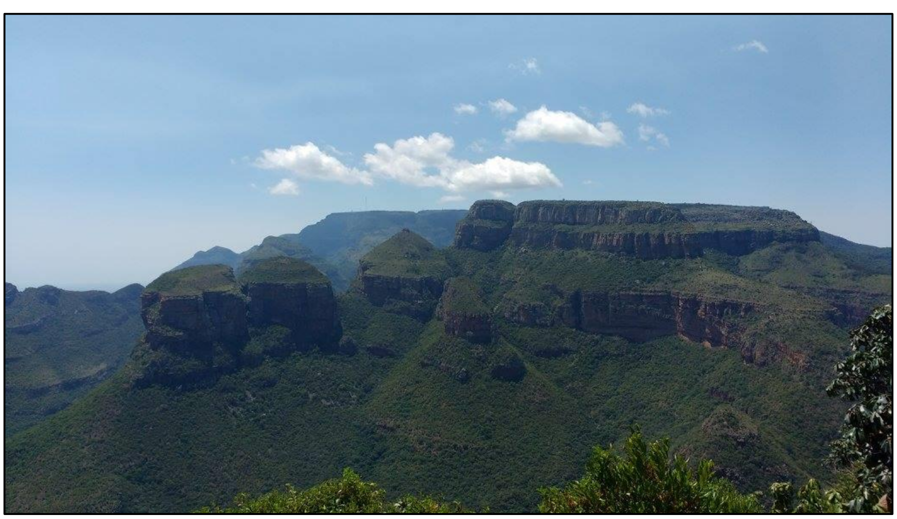


The Dwars Rivier Exposure of the UG1 Chromitite Reef

March 1st, 2016 (Day 2)
Today we drove towards the Blyde River Canyon. En-route we took the opportunity to explore the sediments of the Transvaal Supergroup in outcrop. These sediments were deposited in the early Proterozoic, approximately 2.5 billion years ago.

At the first roadside outcrop, we used a simple scratch test to infer the outcrop was dominantly limestone rather than dolomite, which was bolstered by the absence of reddish weathering stains often associated with dolomites. We further deduced that these finely laminated limestones were laid down in a continental shelf environment, as the limestones were interbedded with distinct cherty layers exhibiting waviness that illuminated the undulations of the deposition surface. Cutting through the outcrop was another feature, which at first blush seemed to be a dyke. However, its soft matrix hosted a plethora of brecciated limestone material, seemingly drawn in from the margins. From these observations, we chose to identify the cross-cutting feature as a hydrothermal event.

We then carried on to the Blyde River Canyon, to see the Three Rondavels, and the Blyde River, which snaked below. After taking in the view and a brief lecture on the local geology, we set out towards Kruger National Park, our destination for the night. In an incredible stroke of luck, not 5 minutes past the park gates, we encountered an elephant at the roadside, flapping its ears in combat of the forty degree heat.



The Three Rondavels at Blyde River Canyon

March 2nd, 2016 (Day 3)
For a few of us, this was a particularly early morning. From the fenced campground of Skukuza, half the group joined two guides – armed with rifles and keen ears – in a walking tour of the park. In the cool early morning, we could hear the distant roar of lions, and encountered all sorts of local fauna. From cautious giraffes to a (thankfully) unobservant rhinoceros, we saw more up close than we ever thought we would.

By mid-morning, the group remerged back at Skukuza, ready to continue our safari. Of course with Willy driving, our sight-seeing was not limited to the fauna, and we took advantage of the drought-drained rivers to look at the polished bedrock. The Archean granites and gneisses were host to beautiful swirls of dark fine-grained restite and bands of coarser felsic material.

The real stars of the day were the animals, of which we saw four of the "big five" animals. Out of lions, rhinos, water buffalos, elephants and leopards, only the leopards remained elusive to us. Nevertheless, we saw hippopotamuses, kudus, baboons, monkeys, zebras and many other animals.

By late afternoon we returned to Skukuza, in time for the other half of the group to go out on their evening field walk, with the hope of catching an up close sight of more of the animals in the dwindling sunlight. That night, we had our first braai (Afrikaans for barbeque), with boerewors, steak and vegetables.

White rhinos in Kruger National Park

March 3rd, 2016 (Day 4)
Our journey out of Kruger National Park towards Barberton proved to be just as exciting as the day before. We passed scores of elephants, kudus, rhinos and even a pack of lions (but still no leopard). What was supposed to be a relatively quick drive became another impromptu safari, as around every bend we needed to slow down to allow a rhinoceros to clear the road, or for an elephant to lumber across.

In Barberton, we were introduced to greenstones – named for the typically dark green mafic minerals of which they are composed – and their significance in the formation of the earliest continents. South Africa itself is composed of several cratons, sutured together at their margins long ago through continental collision. But these chunks of stable ancient crust are the result of suturing of many small, batholithic-dimension landmasses that represent some of the earliest crust on earth.

Our first visit in Barberton was to the beautifully detailed Barberton Geotrail, a series of guided outcrop stops, funded by the local chamber of business. Running from the Swaziland border back towards Barberton, the Geotrail traversed much of the Barberton syncline.

We began at an outcrop of sub-meter to meter wide heavily weathered ultramafic pillow basalts. From the pillow morphology we were able to identify the feeder nipples to some of the pillows, which gave us the ability to infer the upwards direction. Atop the pillow basalt outcrop, we found an outcrop of a stunning layered chert – cyclically alternating dark green, to olive green, to black – transitioning into a discordant layer of chalcedony. By carefully seeking out apparent sag in the chert bands, we concluded that the chalcedony was deposited above the more distinctly banded chert. From this, and the proximal pillow basalts, we hypothesized that the discordant chalcedony could be the result of black smokers at the sea floor.

The second stop of the Geotrail was an outcrop of beautiful volcanic lapilli, indicators of subaerial eruptions. From some of the exposures, we could infer clast size, and even still see the original clasts, rather than just clay casts. Most of the clasts ranged in size from 0.5 to 1 centimeters.

The next stop was a stunning exposure of redbeds, interbedded with jasper (distinguishable by its hardness) and distinct yellowed ash beds. In this outcrop, we found a great deal of evidence for folding and shearing, which was particularly observable in the ash beds. Due to a lack of magnetism, we inferred these redbeds to be magnetite poor. Nearby, we saw evidence for low energy breccias, with little evidence for transport of clasts. This theme continued to the next outcrop, where the layers were clearly broken up but scarcely transported more than a few centimeters. The guidebook refers to these breccias as "tsunami breccias", an interpretation which we challenge on the basis of the evidence for the lack of transport of the clasts.

The final stops were exposures of tidal sandstones, with hints of crossbedding to be found throughout the eroded channels of the outcrop, and a large boulder with thin black lines snaking through. In thin section, the authors of the *Geotrail identified these to be biomats.*

David checking the redbeds for hints of magnetism along the Barberton Geotrail

March 4th, 2016 (Day 5)
Today we visited the banks of the Komati River to find the komatiites, of course named for the river. Komatiites are an ultramafic volcanism, with compositions no longer actively produced on the planet. Our chosen path along the Komati River gave us an excellent overview of the unique textures and features of the Komati Formation.

First, we stopped at an outcrop of a komatiite flow, exhibiting beautiful olivine spinifex textures and a chill-top breccia. To determine 'tops' in the flow, we traced the directions of radial growth of the crystals to trace back to the top surface. We searched for evidence of preferred directionality in the spinifex texture, but none was observed. We observed evidence for a repetition of this pattern, indicating that there were successive flows on top.

Next, we stopped at an outcrop of komatiitic pillow basalts. Drawing on what we learned about pillow morphology the day before, we identified tops through identification of pillow sag, since we could not confidently identify the feeder nipples. Our interpretation of tops was in agreement with the first outcrop.

Evidence for immiscibility in flow units along the Komati River

Our third stop was perhaps one of the most unique of the trip. As succinctly described by Willy, "now this is super cool!" Several flow units exhibited spherulitic structures, hallmarks of liquid immiscibility. Within the grey-green basalts, golf-ball sized felsic spherulites could be found coalescing at the margins. These felsic (and thus less dense) globules must have gradually migrates towards the surface through the much denser komatiitic melts, which we could observe in the pattern of the spherulites.

A beautiful exposure of spinifex textures in the komatiites

Along the other stops, we found more spinifex textures, but the observed mineralogy had shifted drastically. Where before we had observed rather colourless crystals (consistent with the expectation of crystallization from melts with high magnesium numbers), now we observed black crystals. These minerals are thus inferred to be actinolitic amphiboles. There was also further exposures of serpentinized komatiitic pillows. These heavily altered pillows had distinctly magnetic internal margins, but the heavily altered fringes were quite soft, implying any silica produced in the serpentinization process was not retained.

From the Barberton region we began our long drive southwest, to the border of Lesotho along the stunning Drakensberg mountain range in the province of Kwazulu-Natal.

March 5th, 2016 (Day 6)

From our campsite, the distant flood-basalt capped mountains of the Drakensberg were a beautiful sight. After a light breakfast we left for the Royal Natal Park, to look at the rock art of the San people, and to hike towards the base of the magnificent Drakensberg amphitheater, a 1200 meter tall and 5 kilometer wide mountain face.

To view the rock art, we took a brief walk with a local guide to an exposure of sandstone, on which polychrome paintings of thin, agile male hunters chasing impalas and other fauna were depicted alongside the wide-hipped female gatherers. We were guided through reflections of the culture and history of the San people, from their original lifestyles to the impact of colonialism on their culture. Our charismatic guide, who was as eager to learn from us as we were to learn from him, took the opportunity to show us a preserved fossil in the rock, just meters from the rock art. From his own personal research, he proposed that the fossil was a starfish, whereas Willy and Al suggested it could be a type of sea anemone, because of its slender curled arms and upright orientation.

That afternoon, we hiked the gorge towards the base of the amphitheater, with stunning views of Tugela Falls, the world's second tallest waterfall. In the warm afternoon heat we witnessed how turbulent the Drakensberg weather could be, with several shifts to and from thunderstorms occurring in just a matter of hours. While along this hike we did not have the opportunity to see the flood basalts up close, we did have stunning views and a few exposures of the underlying sedimentary units, including the Clarence sandstones and Elliot mudstones.

The rock art of the San People, in the Royal Natal Park

March 6th, 2016 (Day 7)

The Amphitheater, as seen from the gorge hiking trail

In our second day in the Drakensberg area, we took the opportunity to visit flood basalt outcrops. From the Amphitheater Backpackers Lodge & Campground, we drove towards the Sentinel Peak Carpark.

Our first destination was an older road cut, where the basalts had been heavily weathered to the point of almost being unrecognizable to the untrained eye. Curiously, there appeared to be large ‘boulders’ perched throughout the outcrop. However, these ‘boulders’ were actually the result of spheroidal weathering – also known as onion-skin weathering – of the basalts themselves. At the fresher road cuts further along the drive, amygdales became discernible from the matrix. These pipe vesicles, which nucleated at the bottom chill margin of any given flow, seemed to clearly propagate upwards and coalesce near the surface. Some pipe vesicles showed evidence of directionality, allowing us to make an inference about the direction of flow. We discussed the controls on the movement of gas through melts, such as volatile content, viscosity, and the rate of cooling the flow would experience.

In one road cut, we observed a non-planar feature intruding through the basalt. Induced shear was observed by examining the shape of proximal amygdules, whose morphologies differed greatly from the other pipe vesicles. Our inference was that this undulating, discontinuous feature was likely an intruded basalt flow of nearly identical composition. Leaving the Sentinel carpark, we were able to examine a cliff face, on which we could observe hints of columnar jointing, on an incredible scale.

With our time in the Drakensberg coming to an end, our journey took us back towards Johannesburg, to the area of the Vredefort Impact Crater.

March 7th, 2016 (Day 8)

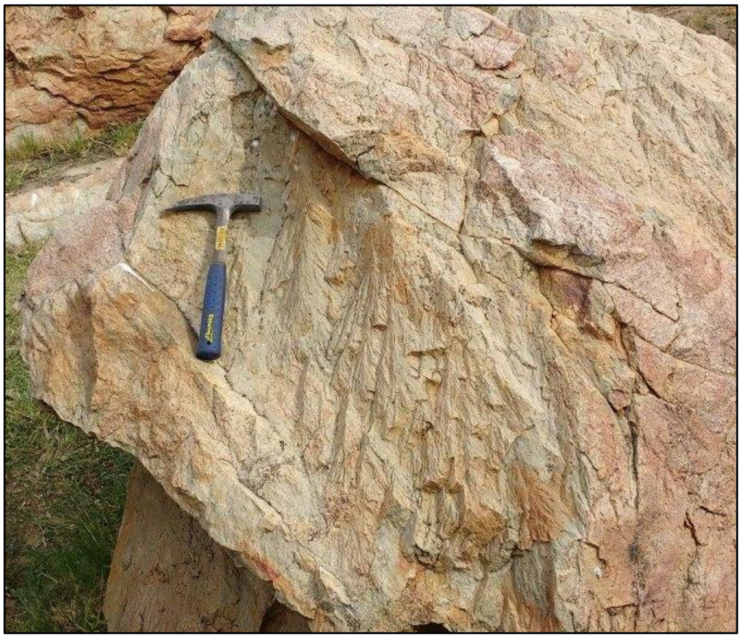
We woke on another sunny morning along the banks of the historic Vaal River. This river was the historic border of the Republic of the Transvaal, a nation which has since been dissolved.

Our first stop of the day was along the river, within the small, strongly Afrikaans community of Parys. On the riverbank, there were beautifully polished exposures of pseudotachylite breccia. This pseudotachylite breccia was formed in the immense Vredefort impact, when a several-kilometer diameter meteor struck the other approximately 2 billion years ago, leaving a 300 kilometer diameter crater and a resurgent dome of Archean granites and gneiss ses. By looking carefully at the mineralogy of these granites, we were able to determine them to likely be I-Type, which is reasonable given the time period in which they formed. The Archean rocks were not the only units affected, with the rocks of the Witwatersrand Basin also being greatly affected.

Our second stop was at quarry outside of Parys, with 3-meter walls of exposed pseudotachylite breccia. Here percolating fluids made glassy pseudotachylites, leaving visible greenish lineations through the rock. The breccia clasts varied wildly in size, from several meters to only a couple centimeters. Between the clasts was the characteristic dark fine grained matrix, composed of both frictional melt and fine grained material resulting from the impact.

Next, we visited two outcrops of shatter cones – the radial structures that are hallmarks of impacts (pictured). These shatter cones almost conclusively show the Vredefort region to be the result of a large impact, and can be used to triangulate the exact point of impact through taking the strike and dips. Shatter cones form when the shockwave propagating through a relatively homogeneous media (such as a sandstones, or a shale) reaches some heterogeneity, which becomes the apex, and nucleus for growth. For this reason, shatter cones are not observed in very heterogeneous rocks, such as the Archean granites observed at the pseudotachylite outcrops. The most well-defined shatter cones we found were in quartzites near the Vaal River.

Taylor, Amelia and Willy investigating the pseudotachylite at a quarry outside of Parys



Shatter cones in quartzites, found along the banks of the Vaal River

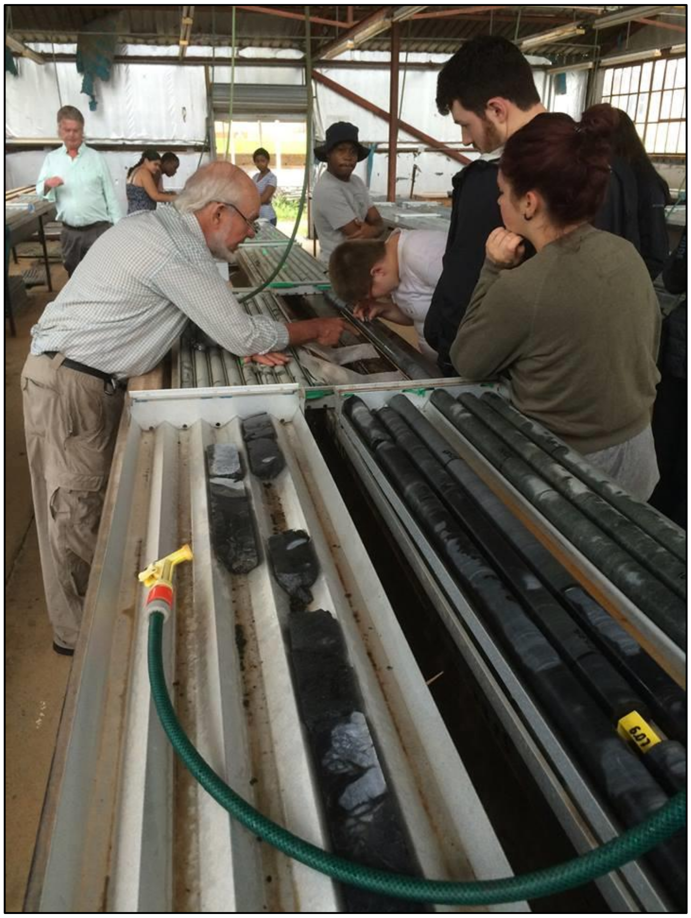
March 8th, 2016 (Day 9)

On the morning of March 8th, we rose before the sun to pack up camp from our Parys campsite, to drive north towards the mining town of Rustenburg. This was the day we had the amazing opportunity to travel over 3 kilometers underground in the Mponeng Gold Mine operated by AngloGold Ashanti. After checking through security and receiving our safety introduction, we were taken to prepare for our venture down. With the expectation of temperatures as high as 30 degrees Celsius and 100% humidity, we changed into the provided coveralls and safety garb. With our two geologist guides, we shuffled through the locker rooms to the cramped hallways leading to the elevators.

In what were essentially steel cages, we were crowded in amongst the miners. Just a few minutes later, we were already two kilometers beneath the surface. After a short walk from the first elevator, we descended the remaining distance to a phenomenal depth of 3.3 kilometers.

From the elevator, we walked about two kilometers, towards an exposure of the Ventersdorp Contact Reef (VCR), which was actively being mined. The tunnels were spacious caverns with shotcrete-covered walls, and a central railway for train carts. As we walked we were given the opportunity to discuss with our guides about topics from mining-induced seismicity to the orientation and size of the VCR. Soon after, we saw the VCR itself, with visible cross beds and beautiful conglomerates. While no gold was visible to the naked eye, we were assured that the reef the ore grade was particularly impressive.

After our tour of the operating mine, we met with Gareth Flitton who provided us with a presentation on the local geology, and the current models to describe how the gold deposits formed, such as the “modified placer” model, and the hydrothermal model. He further described the geomorphology of the ancient landscape in which they believe the gold was deposited. We were also given an opportunity to explore their drill core library, where could see the VCR, as well as the Carbon Leader Reef, and the Bastard Reef, named for its deviously similar appearance to ore-bearing reefs despite being completely barren.



Examining Mponeng Gold Mine's drill cores as Willy lectures

March 9th, 2016 (Day 10)

Lonmin Platinum's drill core library

On the last day of our Johannesburg loop, we were eager to visit the second mine of the trip. Lonmin Platinum kindly hosted our visit at their Marikana site, and while we did not have the opportunity to go underground, members of their geological and metallurgical team gave us a series of fascinating presentations. Topics included the markets for platinum, the site geology, mine sequencing, exploration, and metallurgy. Subsequently, we were given a driving tour of their facility, including the smelters and where their mineshafts were sunk. The geologists were especially candid when describing the events of the massacre that occurred in 2012. Finally, we stopped at their drill core library, where we got to see the distinct spotted 'cats paw' anorthosites, the UG-1 and UG-2 chromitite reefs, and more (pictured above).

By midafternoon we were back on the road, bound for O.R. Tambo airport for our flight to Cape Town. In the Cape Town airport, Nils Backeberg of former McGill PhD fame greeted us enthusiastically, and guided us to our campsite for the night, near Betty's Bay.

March 10th, 2016 (Day 11)

The sea caves at Arniston, looking out into the Indian Ocean

Come morning, we were treated to beautiful views of the cape fold belt. From our campsite we drove to Arniston to see the sea caves where we found carbonates, composed of uncountable numbers of tiny shells. These carbonate faces also had beautiful examples of cross bedding. We took a well-deserved break from geology and spent some time swimming in the Indian Ocean, just off the tip of the continent.

From Arniston, we drove to Stellenbosch, a small wine-growing town in the mountains of the cape fold belt. This charming town, known for its university and characteristic Dutch architecture, was our lunch stop before we continued driving towards Franschhoek, where we would be spending the afternoon. Franschhoek, also nestled in the stunning valleys of the cape fold belt, is another wine-growing hub of South Africa. In Franschhoek, we took it upon ourselves to investigate the terroir of South African wine. We also took the opportunity to learn a little bit about the history

Franschhoek, including the history of its name, which directly translated means "French Corner", as many Huguenots settled the region in the late 1600's.

March 11th, 2016 (Day 12)

Our journey back to Cape Town started with a journey through the scenic Franschhoek Pass, which offered spectacular views of the near and distant folds that undulated across the landscape. Along our descent from the pass, we stopped at a few outcrops, to see the typical quartzites of the region, as well as outcrops of shales which were so heavily weathered that they were scarcely recognizable.

In the midafternoon we arrived back in Cape Town at our downtown hostel. From there, we had the opportunity to explore the city, and to visit the local markets, cafes, and enjoy what Cape Town has to offer.

Wine country in Franschhoek

March 12th, 2016 (Day 13)

In the early morning, we drove to the University of Cape Town to meet with our guides for the day. Nils, who had helped us plan this loop, was ready to take us to explore the peninsula along with another alumni of the McGill Department of Earth and Planetary Science, and emeritus professor David Reid of the University of Cape Town.

We were given an overview of the geology of the peninsula, with opportunities to explore roadside outcrops, a visit to the Cape of Good Hope to see the physical (not geographic) boundary between the Atlantic and Indian Oceans, and finally a visit to a place of an infamous geological debate. The Sea Point granites, just outside of Cape Town, were the subject of debate between Neptunists and those who believed the rocks were of plutonic origin. The debate drew minds as great as Charles Darwin himself, who wrote about the Sea Point granites during his travels. At this outcrop we finished the peninsula tour, celebrating a day of wonderful geology with champagne and watching a beautiful sunset.

March 13th, 2016 (Day 14)
On the morning of our last day, we took advantage of the beautiful weather to hike the Lions' Head, a favourite local hiking trail with wonderful views of Cape Town, Table Mountain, and the ocean. Such a stunning view seemed a very fitting conclusion to a trip full of so many wonderful sites and experiences.

A happy crew of geologists!

Acknowledgements & Thanks

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EPS-Shell Canada Sedimentology Field Trip 2016: Neogene Basins of Southeastern Spain

As part of EPSC 425 (Sediments to Sequences) and a coupled graduate course on sedimentary basins, 14 undergraduate students, 3 graduate students, and I traveled to southern Spain in late February and March to visit the Neogene sedimentary basins of Almería Province, Andalucia. This was the second Spain field trip run as part of EPSC 425 and with the support of Shell Canada, and it was every bit as great as the first trip—minus the hiccup of a significant snowstorm our first few days, when we tried to visit a new area.

Days 1–3. The 17 McGill students and I met at Madrid Barajas airport on Friday, February 26. After a few challenges tracking everybody down and renting appropriately sized vans, we set off for Aliaga, a village about half way between Madrid and Barcelona. This was new area for this trip, and the goal was to study the Aptian Maestrat basin and visit several locations near a carbonate platform-basin transition. Previous work in this region had revealed spectuarly preserved systems tracts and associated sequence stratigraphic surfaces, the likes of which are often difficult to idenitify on carbonate platforms. Unfortunately, although the region was beautiful and looked as promising for a field trip as the papers and guidebooks suggested, this attempt to branch out into older basins in Spain failed when much of the Iberian Peninsula was pounded by an uncharacteristic late winter storm. The 35 cm of wet snow not only precluded any possibility of visiting outcrops, but also added a challenge to our escape to the south of Spain. Fortunately, we managed to plough through several snow drifts and our hearty students pushed the vans up a few snow-encrusted hills as we made our way back to the main highway. After a long day's drive south, which took us through the endless orange orchards around Valencia and across many mountains of Cretacious carbonate and Betic schists, we found an empty hotel near our first field trip stop in the south. All were ready to peal out of the vans and find dinner.

The view from our hotel during an early break in the heavy snowfall
A hint of some really interesting geology shows beneath the snow

Day 4. After an early start, we spent the day in the Sorbas basin, one of several small and geographically distinct sedimentary basins that flanks the basement uplifts in the region. Following an overview of this and the other basins in the area, we spent much of the rest of the day puzzling over spectacular gypsum deposits and associated marl-carbonate cycles deposited during the Messinian. By the time the sun approached the horizon, the students had formulated hypotheses for how orbitally controlled glacial-interglacial cycles could account for the transitions between seafloor (selenite) gypsusm, gypsum supercones (visible in the photo below), and marl. It was time to return to our beachside apartments in Carboneras.

Making sense of the evaporite-marl cycles

Day 5. Having found our bearings in the Sorbas basin the day before, we spent the next day studying spectacular marine to margin-marine sequences of the late Messinian Sorbas Member exposed around the precipitous village of Sorbas. Here, the students could see prograding and shoreface systems (again related to glacioeustasy) and the attendant change in facies. Perhaps most spectacularly, barrier island and lagoon deposits are preserved in three dimensions just behind the village and below the transition from a restricted marine basin to a purely terrestrial basin. After establishing the sequence stratigraphic framework of these strata and describing rare, siliciclastic-dominated stromatolites, the students had the opportunity to explore the Sorbas caves—carved out of the evaporites that occur stratigraphically below the Sorbas Member.

The view behind (to the northeast of) the village of Sorbas. The cliffs below are made up of foreshore sandstone, and the recessive beds above are lagoonal mudstone. The upward continuity of sandstone on the right side of the photo (basinward) reveals the location of the ancient barrier island, and the tongue of sand in the middle of the photo shows spill-over of those sands in a flood-tidal delta

Day 6. Having finished our work in the Sorbas basin, we continued the next day to the Tabernas basin, which although tenuously linked to and coeval with the Sorbas basin, is filled by very different strata. We began the morning walking through a transition from coarse alluvial fan deposits into fan-delta deposits, which provided a perspective on the source of sediments that rapidly filled this basin. We spent the rest of the day in the axis of the basin, where we investigated turbidites and gravity flow deposits, some of which filled deep subaqueous canyons and tectonically confined sub-basins. We also found the Gordo Megabreccia, a thick and jumbled unit indicating massive failure of the slope, presumably related to Neogene seismity in the basin.

The group sitting on turbidites and debris flow deposits filling a deep, subaqueous channel carved into marls in the axis of the Tabernas basin

Day 7. Spending the night in Tabernas gave us the opportunity for a full day as we made our way towards Guadix. We started near the small town of Alboduloy, which sits on the northwestern margin of the Tabernas basin. This is where we had met Spanish sedimentologist Fernando García-García on the previous field trip and were first introduced to extraordinary, cyclic gilbert delta deposits, exposed in all their glory in the walls of a small river. This spot is quite simply a sequence stratigraphy laboratory, and we spent a few hours sketching the bottomset, clinform, and bottomset beds of multiple cycles and understanding how the interplay between eustatic sea level fluctuations and subsidence influence the distribution of coarse- and fine-grained sediments within the delta complex. In places, cobbles deposited in distributary bars in the topset beds are imbricated shoreward (up the slope of the accretionary cross beds), indicating reworking by waves. On other spots, the bars are capped by small coral reefs, which form during the transgressions.

Unfortunately, the canyon walls are in shadow in the morning and not easy to photograph. Nevertheless, the clinforms of two cycles are readily visible in the center and bottom right of the photo, and a thick set of coarse-grained topset beds can be seen in the upper left of the photo

After lunch, we continued to the La Peza reservoir on the southern margin of the Guadix basin, where the cyclicity is expressed in marl to sandy carbonate rhythms. These cycles, dipping northward, had previously been misinterpreted to be clinform deposits, but García-García recognized that they represent instead a tide- and storm-dominated mixed clastic-carbonate ramp system that was subsequently tilted by uplift in the Sierra Nevada. Unfortunately, construction near the base of La Peza dam prevented us from seeing the impressive overturned cross-beds there, but we did find cool ripples migrating up the lee-side of large subaqueous dunes. Later that evening, a group of us retraced our steps to the Bodega Calatravas, a great tapas place we had found on the previous trip.

The group at La Peza Reservoir, on the north side of the Sierra Nevada (visible in the background on the right) on the penultimate day of the trip. The Miocene-aged, dipping beds in the background were previously interpreted as clinoform deposits, but are more likely cyclic ramp deposits

Day 8. This was our last day in the field. We spent the morning looking at the Gilbert fan delta system where coarse-grained sediments were deposited in the bottomsets and foresets and clinoforms shrunk as base level dropped and the basin filled up. In the exposures near Dehesas de Guadix, the students could see explicity a falling stage systems tract (FSST) and an associated incised alley. By the time we wrapped up the visit to this spot, the warm and clear weather we had enjoyed in the south of Spain to date gave way to another cold system. It was time to hit the road for Toledo, where we sould spend our last night together as a group before continuing on to Madrid and finding our way back to Montreal.

A Gilbert delta deposited on the uplifting flank of the Guadix basin, north of the Sierra Nevada. Notice the decreasing height of the foresets, reflecting infilling and shallowing of the basin

Field School II & III

French Massive Central
Lavoute-Chilhac, France
May 2016

The French Massif Central is part of the Variscan belt and represents the orogen in which Europe was put together. The area was an ocean at ~450 Ma, with deep-sea sedimentation, followed by an accretionary prism sequence as Gondwana started moving north and subduction was initiated. The continental suture was established at ~380 Ma, at which time a mountain belt rivaling the Alps had been constructed. Thermal equilibration initiated extensive granite plutonism, with associated Sn-W-Mo ore deposits. Crustal delamination subsequently led to orogenic collapse and formation of abundant, but small, strike-slip basins. These high-elevation basins (evidence for glacier activity) were largely filled with peat in the Stephanian. Delamination also sent a heat pulse through the crust, which cooked this peat to anthracite and liberated metamorphic fluids, which formed major Sb ore deposits. During the waning stages of this hydrothermal activity, fluid flow through the basins formed barite-fluorite deposits with associated Pb-Zn ores. The area was subsequently eroded down to a peneplain sectioning mid-crustal levels. During the opening of the Atlantic, the area was subjected to extensional tectonics with development of the Limagne graben. At the same time, possibly even initiating the extension, a hotspot established itself and produced abundant magmatism, including the mostly basaltic Chaîne des Puys, and the Si-undersaturated Cantal and Mont Dore complexes. In short, the area has it all!

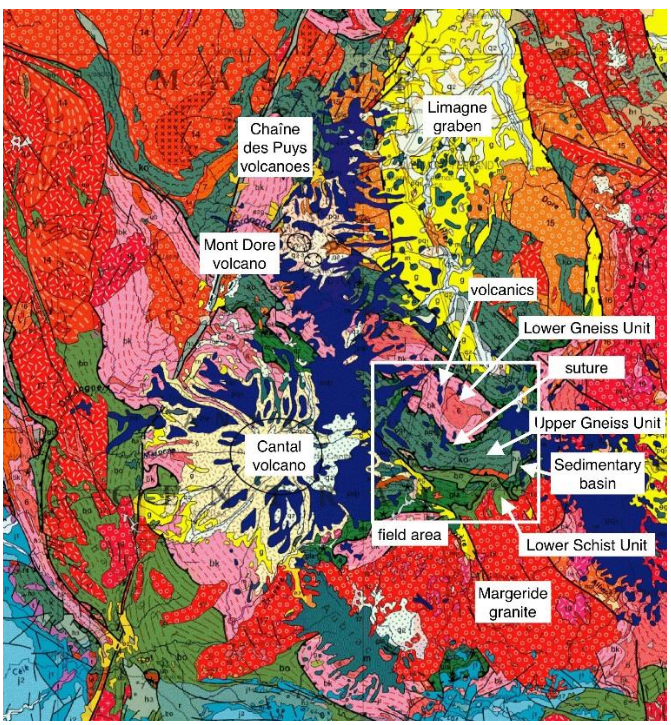
The field site is located around the village of Lavoute-Chilhac, with Langeac as the nearest large town. This site is on the major suture of the orogen and in the hart of the Massif Central. The geology includes:

- Metamorphic basement with granulite-facies felsic-gneiss dominated Upper Allochton (shows local partial melting), amphibolite-grade metapelitic-schist Lower Allochton, and amphibolite-facies shearzone in between with relics of mafic eclogite and serpentinised peridotite.

- The shearzone represents one of the major orogenic sutures in Europe and has a displacement of at least 200km. It contains stunning ductile and brittle deformation textures, and is a mélange with well-developed metasomatic reaction rims on foreign blocks.
- Post-orogenic plutonism is represented by the Margeride Granite, which crops out on the southern border of the field area.
- The Langeac basin is an example of the strike-slip coal-filled basins related to orogenic collapse, and this is situated in the middle of the field area.
- The area is on the intersection of two major ore provinces in Europe: the Langeac fluorite belt and the Massiac Sb district. These were mined from Roman times until 1970 and abundant remnants of these mining activities are dotted around.
- There are abundant basaltic lavaflows and spattercones on this basement, and the Chaîne des Puys, Cantal and Mont Dore complexes are near by.

The field school consists of:

• 2 days of introductory excursion to familiarize the students with the area and its geology
• 7 days of independent geologic surface and transect mapping
• 5 days of regional geochemical surveying of streams (3 days of field sampling and 2 days of analyses of these samples in our field laboratory for major and trace elements).
• 3 days of geochemical and geophysical exploration in a grid project (2 days of field sampling and self potential measurements, and one day of laboratory analyses).
• 2 days conducting a seismic survey in the Limagne graben



In addition, students will participate in excursions to:

- the Chaîne des Puys volcanic chain west of Clermont-Ferrand, which focuses on volcanic landforms
- the Cantal volcanic complex with emphasis on igneous petrology
- the sedimentary basins, including the Carboniferous coal-bearing basin of Blassac and the Limagne graben

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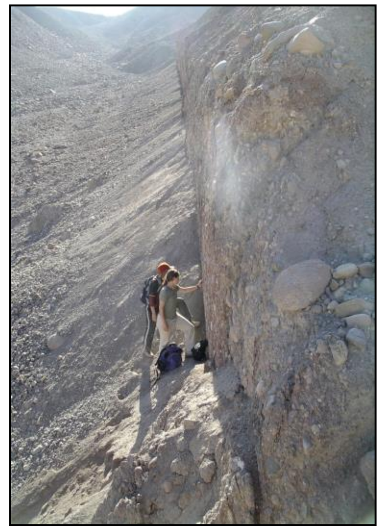

Left Photo: Late Holocene moraine-dammed lakes in the Cordillera Huayhuash, Peru
Right Photo: Purgatoria Fault scarp in southern Peru

DAWSON FIELD STUDY SUPPORT

Don Francis, Jonathan O'Neill *(Ph.D.'09),* and Shake

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McGill's Roddrick Gates on a Spring day.